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REPORT OF THE ENTOMOLOGIST

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 1, 1927.

SIR: I submit herewith a report of the work of the Bureau of Entomology for the fiscal year ended June 30, 1927.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. W. M. JARDINE,
Secretary of Agriculture.

DECIDUOUS-FRUIT INSECT INVESTIGATIONS

Investigations of deciduous-fruit insects have been carried out under the direction of A. L. Quaintance, as formerly.

CODLING MOTH

Investigational work in connection with the codling moth has been directed principally to the problem of arsenical-spray residues on apples and pears. This work is being done in cooperation with the Bureaus of Plant Industry and Chemistry and Soils and with several of the States. The Bureau of Plant Industry is giving special attention to the removal of spray residue by processes of washing with acid, and the Bureau of Chemistry and Soils is cooperating in the study of various insecticides which may be utilized in place of lead arsenate in the control of this pest. These spray-residue studies are being carried out both in the laboratory and in the field. In the laboratory, feeding and other experiments under accurate control conditions are under way to determine, for many materials, the proper dosage for codling-moth larvae of different ages. In the field orchards are being sprayed with a considerable list of possible substitutes for lead arsenate to determine their effectiveness on the insect and safety to the foliage. Among such materials under experiment may be mentioned different forms of arsenates of zinc, aluminum, iron, barium, calcium, copper, titanium, manganese, and mag-

nesium. In addition, various silico-fluorides are under test as well as numerous other compounds. The results of the work, which was begun in the spring of 1927, can not be reported upon at this time, although the indications are that some of these arsenicals may be used in place of arsenate of lead, thus meeting the objection to lead in this compound.

Field work relating to the codling moth is under way at the laboratories at Yakima, Wash., Wichita, Kans., Vincennes, Ind., and Bentonville, Ark., in cooperation with the agricultural experiment stations of these States. In addition to the laboratory and field studies indicated, experiments are under way in the use of bait traps in orchards for the destruction of the codling moth, with results moderately favorable. Thus, at Yakima, Wash., in a block of trees baited and sprayed, only 10 per cent of the fruit was wormy, whereas in an unsprayed and unbaited block 20 to 25 per cent of the fruit was wormy. Tests of various sprays as ovicides and larvicides are being carried on. Certain oil emulsions under test killed 98 per cent of the eggs deposited, but had less effect on eggs deposited after spraying. Nicotine sulphate at proper strength is also under test and results are promising.

Attention is also being given to auxiliary methods of codling-moth control, as in better packing-house and orchard sanitation and in the use of bands around the limbs and trunk of the trees for the destruction of cod-

ling-moth larvae. It has been found possible to treat these bands with certain chemicals which kill the larvae after they have spun up. Among the most effective of these are certain naphthalene derivatives, as alpha and beta naphthylamine. It is believed that by the proper use of these automatic band traps the codling-moth population in orchards can be very greatly reduced, thus modifying the necessity for spraying, which often involves objectionable residues on the fruit at the time of harvesting.

As a part of the investigation looking toward the avoidance of arsenical-spray residues, a study has been begun as to the behavior of the insect under varying climatic and other environmental conditions. In addition the likes and dislikes of the larvae and adults are being inquired into, in the hope that something of value in control may be found. In the laboratory at Washington, D. C., extensive investigations have been begun to find and perfect, if possible, other insecticides than arsenicals which may be used on fruit and vegetable crops.

BLUEBERRY MAGGOT

The general situation in regard to the blueberry maggot in Washington County, Me., has not changed materially since the last report. The washing machines devised by the Bureau of Chemistry will enable the canners to continue to operate their plants until satisfactory field control can be worked out. The biologic work on the insect has included studies of such questions as depth of pupation, the effect of burning-over blueberry land, the species of berries infested, and studies of parasites. Special attention is being given to experiments in the application of poisons, principally calcium arsenate, and also to studies of the quantity of arsenical residue left on the fruit at harvest time. Comparative studies of the apple and blueberry maggots have been undertaken and a difference in size of the insects in all stages has been noted. Much information is being obtained on the parasites of this insect. *Opius melleus* has been reared in large numbers in emergence cages. This species is undoubtedly an important factor in the natural control of the blueberry maggot. In the dusting experiments sufficient acreages have been treated to permit the drawing of tentative conclusions as to the value of this work. It is believed that the flies can be killed before oviposition

by timely applications of calcium arsenate. Some injury to foliage will result from this treatment, but it is felt that this can be corrected. Owing to the general practice of washing the berries before canning, it is believed that the residue of the arsenical insecticide will hardly prove a factor.

PEACH INSECTS

ORIENTAL PEACH MOTH

Special attention has been given to the oriental peach moth at the laboratories at Riverton, N. J., and Fort Valley, Ga. In New Jersey a survey was made of all parasites known to attack any stage of the insect, and two species, *Macrocentrus ancylovora* and *Trichogramma minutum*, have been given special attention. At times during the season from 90 to 100 per cent of the larvae found in peach twigs were parasitized by the former species. An intensive study has been made of baits attractive to the oriental peach moth. Several products, particularly corn sirup, refiners' sirup, brown sugar, and other sweet products at dilutions of 5 or 10 per cent attract many moths. Several fermenting fruits are also attractive. Tests were made in three orchards with baits as a means of control, but the results were unsatisfactory. A study has been completed on the response of the adults to colored lights. The moth appears to prefer colors near the violet end of the spectrum. Ultraviolet light is also rather attractive. Beginning with the spring of 1927 a more serious attempt than heretofore has been made to test insecticides for the oriental peach moth. One specialist is devoting his entire time to this phase of the work, which includes studies of ovicides as well as larvicides. Attention is being directed toward the possibility of developing a repellent which may be used in orchards during the period of growth.

In Georgia the life-history studies of the peach moth were concluded during the fiscal year. It has been ascertained that there are from five to six generations with a partial seventh each year according to weather conditions. Further observations indicate that the peach moth is not likely to become a serious pest in southern districts.

PLUM CURCULIO

Extensive laboratory experiments have been made at the Fort Valley, Ga., laboratory to determine the tox-

icity of sodium and calcium fluosilicates, as well as a number of arsenicals, to the plum curculio on peach. One of the facts revealed as a result of these tests was that sodium fluosilicate against this insect is rendered materially less toxic by the addition of lime, whereas without lime it is very toxic to the insect, even more so than lead arsenate. Unfortunately, sodium fluosilicate without lime can not be used on peach trees by reason of the severe injury to fruit and foliage. It is possible that this situation may be corrected by further experiments. The arsenates of tricalcium, barium, and zinc, in the order named, were also found rather toxic to the insect. The arsenates of magnesium, manganese, and aluminum were less toxic.

In connection with further tests of materials against the peach-tree borer, applications of alpha naphthylamine were made to 1, 4, and 6 year old trees. Although no injury to the trees resulted, the chemical was found worthless against the insect.

Further studies of the so-called "cat face" of peaches have been made at the Vincennes, Ind., laboratory in cooperation with Purdue University Agricultural Experiment Station. The caging tests of 1926 were repeated in the spring of 1927, and again showed conclusively that some of the injury is caused by the tarnished plant bug. Four additional species of stink bugs, however, were found as contributing to the trouble. These all belong to the genus *Euschistus*, are very similar in general appearance and life histories, and probably can be controlled by one and the same method. These insects feed on a long list of other plants, such as weeds and cover crops, which may be present in or close to the orchard. In a general way, observations indicate that the injury is worse in orchards in which weeds were allowed to grow freely the previous season, or which are close to rough, uncultivated land.

ORCHARD INSECTICIDES

ARSENICALS •

A chemical study of the burning of peach foliage and fruit by arsenical sprays and dusts has been under way. Evidence thus far indicates that lead arsenate and calcium arsenate must be decomposed upon the leaf with the freeing of water-soluble arsenic before injury will occur. There was a considerable accumulation of soluble arsenic upon the leaf surface before its

presence could be shown within the leaf. As much as 0.001 milligram of arsenic pentoxide can be present within a leaf without injury being indicated. However, when the quantity is increased to 0.002 milligram, arsenate-pentoxide injury begins to appear. It was found that all materials which, when added to lead arsenate, reduced injury did so by reducing the quantity of soluble arsenic in solution. The problem resolves itself into the prevention of decomposition of a soluble lead arsenate into soluble arsenic. This is best accomplished by regulating the P_H of the spray solution to the composition. This promising field of investigation will be given further attention.

OILS

Further studies of oil emulsions, especially for the control of the San Jose scale, have been made. These included the influence of the quantity and kind of emulsifier used, and the influence of Bordeaux mixture on the effectiveness of the oil emulsion when the two are used in combination. In addition the possibility of the use of highly refined white oils in the summer on peach is being investigated. It has been found that the use of Bordeaux mixture with oil emulsion at low concentrations in peach spraying for the simultaneous control of peach-leaf curl and the San Jose scale tends to reduce the efficiency of the oil spray materially at concentrations up to 1.5 per cent of actual oil; at higher strengths under experimental conditions no difference has been evident. No injury to dormant trees has resulted from repeated annual treatments of oil emulsions up to 20 per cent of actual oil. In Georgia, for instance, peach trees have received the fifth consecutive annual treatment of 3 per cent oil emulsion without apparent damage. Definite experiments to determine the danger limit on peach trees by all concentrations show that a spray containing less than 25 per cent of actual oil caused no injury. The twigs, however, are killed at the tips by the 25 per cent strength, and sprays containing 40 to 65 per cent of oil have caused severe injury, killing branches almost back to the trunk. At the Fort Valley, Ga., laboratory attention has been given also to the standardization of the oil content of lubricating-oil emulsions, and this has proved very beneficial to the fruit grower.

Oil investigations in the laboratory in cooperation with the Bureau of Chemistry and Soils have been contin-

ued with special reference to the toxic effect of petroleum oils on aphids with relation to the size of the oil drops. The results of this work have recently been published in the Journal of Agricultural Research. Investigations have been started in connection with the arsenical-residue studies on the action of organic compounds as stomach poisons. While considerable time was necessary to organize this work properly, it is now well under way, and results of importance are anticipated.

DIPYRIDYLS AND ALLIED COMPOUNDS

During the past year a report on this subject has been published under the title, "Toxicity of Dipyridyls and Certain Other Organic Compounds as Contact Insecticides." In all, 35 compounds in this series have been prepared and tested as insecticides, and among these is one which has repeatedly shown high toxicity. This project, which is being carried out in cooperation with the Bureau of Chemistry and Soils, will be continued.

PYRROLES AND RELATED COMPOUNDS

The work done with these compounds, also in cooperation with the Bureau of Chemistry and Soils, has resulted in the development of a number of compounds which have been prepared and tested for insecticidal action. Effort has been made to synthesize compounds that are closely related to nicotine, and valuable information on the subject is being accumulated.

GRAPE INSECTS

GRAPE BERRY MOTH

The investigation of grape insects has been directed largely toward obtaining information on means of controlling the grape berry moth, and at the same time avoiding an undesirable quantity of spray residue on the fruit at harvest time. It is clear that the usual sprays against the second or later broods of this insect will be objectionable from the residue standpoint. The investigations, therefore, include studies of such points in cultural practices as may effect a reduction of the overwintering brood of the insect, thus contributing to its control. Various methods of applying sprays against the first brood are under investigation and will be continued. A study of conditions in localities where the grape berry moth is most destructive shows it to be imperative to greatly develop supplemental control

measures and to place greater emphasis on more thorough work against the first brood, in order to reduce injury to the minimum. The following four principal lines of work have been commenced: (1) An investigation of the cultural practices thought to effect a reduction of the overwintering brood of the berry moth in vineyards. In cooperation with growers, large-scale cultural treatments are under way with this objective in view. (2) An effort to ascertain the degree of grape berry moth control which can be secured with arsenical mixtures applied against the first brood. (3) An effort to ascertain to what extent residues left from midseason applications of lead arsenate may be reduced by changes in the mixtures formerly used. This work includes field tests of mixtures applied earlier than has been the usual practice. It also includes tests of mixtures containing a decreased dosage of lead arsenate, and tests of spreaders, such as oils, thought to be less adhesive than the resin-fish-oil soap commonly employed. (4) Tests in vineyards to ascertain what arsenicals or other materials may be substituted for lead arsenate, especially in late applications, in view of the objection to the lead itself.

The widespread interest in vineyard dusting, caused by a demand for a method requiring less time than spraying and one which might permit late applications of arsenicals for the berry moth, has necessitated attention to this subject and it will be further emphasized another season.

THE ROSE CHAFER

Tests looking toward control of the rose chafer in vineyards have been continued in cooperation with the State department of agriculture and State extension service of Pennsylvania. A large number of materials have been under test, all in comparison with a mixture of lead arsenate and molasses or glucose, which has shown a high percentage of control. Doubling the arsenical dosage increased the death rate of the insects, but apparently gave no additional protection to the blossom clusters. It was ascertained that the proper time for applying sprays is exceedingly important, the most satisfactory control being obtained by spraying when the beetles first migrated into the vineyards and commenced feeding. Pyrethrum-soap emulsion was found to be highly toxic, killing a high percentage of the beetles within a 24-hour period after spraying.

The use of this material, however, affords no protection against the incoming migrants. Dusts of sodium fluosilicate and of barium fluosilicate and sprays of sodium fluosilicate in Bordeaux mixture, while slowly toxic to the beetles, afforded no protection against feeding. Burning of both blossom clusters and foliage resulted from the use of sodium fluosilicate. A number of attractants, including essential oils, alcohols, and fruit juices, were tested, but none proved effective in attracting the insects.

GRAPE LEAF HOPPERS

Further experiments with nicotine sulphate, applied just as the nymphs became injurious and at the time most of the eggs of the overwintering brood had been laid, confirm the results of previous tests as to the ovicidal action of nicotine and show that more complete protection of the vines can be obtained by spraying earlier than has been the usual practice. Experiments under way include tests of a number of oils, preparations of Derris, etc. A commercial Derris preparation has shown results on the nymphs of grape leaf hoppers which compare favorably with results obtained with 40 per cent nicotine sulphate, but the results to date indicate that the ovicidal action of this material is inferior to that of nicotine. Dust applications of nicotine against the nymphs of the grape leaf hoppers have shown fair control, but the percentage of kill is lower than that obtained from liquid applications made with vineyard spray booms.

PREVENTING SPREAD OF THE JAPANESE AND ASIATIC BEETLES

This work has continued under the direction of Loren B. Smith.

THE JAPANESE BEETLE

In the fiscal year the Japanese beetle was found to be established in the States of New York and Connecticut. Several colonies were discovered in Kings, Queens, and Nassau Counties on Long Island, and in Westchester County, N. Y., and in the city of Stamford, Conn. The insect spread westward as far as Easton, Allentown, Bethlehem, Lebanon, and Harrisburg, Pa., besides establishing numerous colonies in northern New Jersey. The spread to the southward was very small, and only one additional township in Delaware was found to be infested. A single beetle was discovered in the city of Washington, D. C.

Two beetles were found in the Loudon Park Cemetery, Baltimore, Md. A small colony of beetles was discovered at Gettysburg, Pa., although no additional beetles were found between that point and the area then under regulation in Pennsylvania.

Within the infested area the beetles became exceedingly numerous over a region of approximately 700 square miles. The city of Philadelphia was invaded several times during the summer of 1926 by large numbers which apparently flew from the heavily infested regions in New Jersey. The presence of large numbers of beetles in the freight yards greatly complicated the effective enforcement of the quarantine on farm products.

The damage to fruit trees and ornamental plants continued to be as severe as in previous years. A small area near Riverton, N. J., where the beetles have occurred in the United States for the longest time, apparently was not so heavily infested as in previous years. In Burlington County, N. J., which has suffered the most severe losses from the Japanese beetle, well-cared-for orchards are being protected from attack, although considerable additional expense is entailed to the fruit growers through the extra spraying of arsenicals which is necessary. In the suburban regions of Philadelphia shade trees, shrubs, ornamental plants, and garden crops are suffering increased damage as the beetles are becoming more numerous. The heavily infested area comprises less than one-tenth of the area under quarantine, and its increase is relatively slow compared with the annual increase of the infested territory as a whole.

Appropriations during the year were approximately the same as they were during 1926. The work of certification of nursery stock and farm products, the movement of which is regulated under State and Federal quarantines, has been greatly increased on account of the larger regulated area. The investigational phases of the work have been broadened to meet the new problems continually arising. Investigational projects are being completed as fast as possible, and reports on several phases have been prepared or are in course of preparation for publication.

INSECTICIDE STUDIES

As a result of several years' exhaustive study a coated lead arsenate has been developed which gives in-

creased protection to foliage and fruit, and kills a much larger proportion of the insects visiting the plants than the commercial acid lead arsenate. From 60 to 70 per cent of all Japanese beetles visiting trees or plants sprayed with this material during the summer of 1926 consumed a lethal dose. Since this coated lead arsenate has excellent adhesive qualities it can not be used on fruit or plants intended for food without danger to the consumer. It has also been found unsafe to apply acid lead arsenate in sufficient quantity to give adequate protection to certain varieties of peaches and apples which ripen early in the season. It has been necessary, therefore, to begin an extensive study to find substitutes for arsenicals which, used on fruit and vegetables, will protect the plants from the Japanese beetle without danger to the consumer. Over 200 chemicals are being investigated, and several have been found which offer a possible solution of this difficult and important problem. The benzol and naphthalene derivatives are being given special attention, as also the possibility of developing a cyanide which will be effective for a short period, and will then disintegrate and disappear before the products to which it is applied are to be harvested.

Because of certain difficulties encountered in the use of a pyrethrum soap developed as a contact insecticide by the Japanese-beetle project two years ago, a detailed study of various kinds of soap and their action on insects has been undertaken. This has led to considerable improvement in the preparation of a contact insecticide for the Japanese beetle. The commercial use of geraniol is being developed. This material is exceedingly attractive to the Japanese beetles and will concentrate them in large numbers in a relatively small area, where they can be killed by a contact insecticide. A trap baited with geraniol has been devised which will capture from 3 to 4 quarts of beetles in one day.

The carbon-disulphide emulsion developed last year has been found to have certain qualities which render it unsuitable for use in cold weather. It has therefore been necessary to continue the studies of emulsions of this material with the object of developing one which will not stratify in temperatures as low as 32° F. The carbon-disulphide emulsion developed at the Japanese-beetle laboratory is in general use in many parts of the country for the control of other insect pests.

Investigations of the use of lead arsenate to control Japanese-beetle larvæ in soil are being continued. It has been found that this material when placed in soil at the rate of 1,500 pounds to the acre is effective for a period of at least five years. It is now being successfully used to control Japanese-beetle larvæ and other soil-inhabiting insects on many of the golf courses near Philadelphia.

The effects of certain colors on the Japanese beetle are being investigated, since it is believed possible that advantage can be taken of the reaction of the insect to colors as a means of increasing the effect of certain insecticides that are being developed for its control. Furthermore, chemotropic studies are being made with reference to both attractive and repellent odors.

As the quarantine regulations governing the movement of nursery stock contemplate the treatment of soil to free it from any possible infestation of the insect before shipment, much work has been necessary in developing means of treatment for numerous varieties of plants. Over 1,000 varieties of nursery and ornamental plants are grown commercially in the area regulated on account of the Japanese beetle, approximately 50 per cent of which must undergo chemical treatment before certification for shipment to points outside the regulated area. Carbon disulphide has thus far been the principal means of exterminating infestations in or about the roots of nursery stock. During the year it has been possible to develop a hot-water treatment for certain types of nursery stock with soil about the roots. The adoption of this treatment has been estimated by one nurseryman to effect an annual saving of \$17,000 to his nursery alone. Chemical studies are being conducted of solid naphthalene derivatives as soil insecticides and of the comparative toxicity of various organic sulphur compounds, particularly the xanthates and mustard oils. Volatile organic compounds, toluidine compounds, and inorganic cyanides are also being studied.

PARASITE INTRODUCTION

Progress in the introduction and liberation of foreign parasites of the Japanese beetle has continued during the year. Shipments of parasite material are being received continually from Japan, China, and India. Seventeen species of parasites of this insect have thus far been discovered. Very successful results are being ob-

tained in the introduction of several species of solitary wasps belonging to the genus *Tiphia* as a result of the discovery of a method of shipping the live adult wasps from Japan, Chosen (Korea), and China to the United States. The bureau is thus enabled to make large shipments of these parasites with relatively small mortality en route. During the autumn of 1926 it was definitely proved that *Tiphia popilliavora*, an important parasite of the Japanese beetle in Japan, has become established in New Jersey as a result of three years' liberations. Although the established colony is still very restricted in area, the degree of parasitism on the Japanese-beetle larvae has reached approximately 15 per cent, and the colony appears to be in a vigorous condition. The introduced tachinid *Centeter cinerea* increased the area of its distribution in New Jersey and Pennsylvania from approximately 48 square miles to 60 square miles during 1926. At the close of the fiscal year there is evidence of further spread of the established colonies of this parasite. As this is the primary parasite of the Japanese beetle in its native home, it is felt that its establishment in this country will aid greatly in the eventual control of the beetle. Large shipments of *Ochroemeigenia ormioides*, *Prosenia siberita*, and *Dexia ventralis* were received in New Jersey in 1926. During the year it has been necessary to curtail the parasite work in China because of unsettled conditions in that country. Other species of parasites have been found in India which offer possibilities, provided that they can be successfully shipped to this country. A shipment of over 25,000 cocoons of an unnamed *Tiphia* was made from India during 1926.

ECOLOGICAL STUDIES

The studies of the reaction of the Japanese beetle to its environment are being continued. These should be of help in determining how important a pest the Japanese beetle may become in other sections of the United States. General ecological studies are being continued to determine the reaction of the beetle to temperature, moisture, and other natural conditions. Further observations are also being made on the life history and biology of the beetle.

QUARANTINE AND INSPECTION

The Bureau of Entomology, cooperating with the Federal Horticultural Board and with the States of New

Jersey, Pennsylvania, Delaware, New York, and Connecticut, has continued its efforts in the enforcement of Federal and State quarantines to prevent the spread of the Japanese beetle. Every effort has been made to enforce the quarantine in the most effective manner. A revision of the quarantine in the fall of 1926 brought under regulation an area of 13,919 square miles, including the city of New York, portions of Westchester, Kings, Queens, and Nassau Counties, N. Y., and two townships in Connecticut, including the city of Stamford. This area contains more than 11,000,000 people. During the summer of 1926 the inspection of farm products was required between June 15 and October 15, and this included inspection of sweet corn, peas and beans in the pod, cabbage, parsley, carrots, beets and onions with tops, lettuce, outdoor-grown flowers, hay, straw, unthreshed grains, and forage crops. The quarantine regulations also required the inspection of nursery, ornamental, and greenhouse products, sand, soil, earth, peat, compost, and manure.

The general procedure in quarantine enforcement was much the same as for the last several years. Inspectors were stationed at points convenient to the areas where restricted articles were grown and were subject to call by the growers when the inspection of any restricted articles was required. To prevent the movement of contraband articles, patrols were established on most of the roads leading out of the regulated area, their duty being to make sure that no trucks or other vehicles passing out of the regulated area carried uncertified products. In Philadelphia a special platform was established at a point convenient to the railroad yards and to this platform all produce that was being shipped from the markets was hauled for inspection and certification. At certain times during the summer of 1926 the presence of large numbers of beetles in the business district made it necessary to discontinue temporarily the inspection and certification of farm products from Philadelphia.

As a basis for the certification of nursery stock having soil about the roots, several methods of soil treatment have been devised whereby it is possible to destroy any infestation of the Japanese beetle which may exist in such soil. A separate organization has been developed, charged with responsibility for making all soil treatments, so that soil and plants with soil about the roots can be certified under

the Japanese-beetle quarantine. This organization has consisted of men thoroughly trained in the specific methods of soil treatment assigned them. The most rigid restrictions are enforced with respect to the application of these treatments so that no possible infestation can escape the treatment. In all, 29,804 trees and plants were treated during the season of 1926 for shipment to points outside the Japanese-beetle area. Of these, 1,710 plants were refused certification after treatment because conditions arose which caused some doubt as to the efficacy of the treatment in these cases. A continual check upon the efficiency of the treating solutions and methods is maintained by means of a check-up system. In addition to the field treatments, 4,359 roots and perennial plants of such a nature that they could not be inspected were chemically treated and certified for shipment to points outside the area.

During the year approximately 7,000 carloads and 46 barge loads of sand were shipped under certification from the Philadelphia territory. It is necessary when such sand or soil is shipped from an infested district to fumigate it before it is certified. In New Jersey 21,110 cars and 818 boatloads of sand and soil, consigned to 27 States and Canada, were shipped from the regulated area.

The total number of packages of farm produce certified from the regulated area during the year was 1,277,149, the total number of nursery plants certified was 33,518,380, and the total number of beetles removed from farm products was 141,998.

During the year a number of violations of both Federal and State quarantines occurred. Prosecutions were completed in 13 cases of violations of the Federal quarantine regulations, 8 of these arising from the interstate shipment of uncertified shipments of nursery stock and 5 from the contraband movement of farm products. Convictions were obtained and fines imposed amounting to \$1,100. Two cases of violations were prosecuted under the Pennsylvania State quarantine and fines of \$120 were collected. Two cases were prosecuted under the New Jersey State quarantine and \$100 in fines was assessed.

SCOUTING WORK

Scouting to determine the spread of the Japanese beetle is systematically conducted each year by crews of men stationed outside the known infested

area. The scouting crews are assigned definite territories and these are covered at regular intervals during the summer when the adult beetles are in flight. When they find infestations they are moved farther out from the known-infested territory. In this way it is possible to obtain fairly accurate knowledge with respect to the dispersal of the Japanese beetle each year.

It has been possible during the year to maintain an effective organization both from the standpoint of the shipper and from that of the enforcement of stringent quarantine regulations. With the addition of new territory and with the inclusion of New York City, greater difficulties are arising in connection with effective enforcement. The increasing abundance of the beetles in Philadelphia during successive summers is undoubtedly increasing the possible avenues by which the insect may be carried to points outside the regulated area. Although the unavoidable natural spread of the Japanese beetle by flight seems great, judging from the number of square miles included in the regulated area, it is believed that the regulations in force have prevented long-distance spread through the agencies of commerce, for the beetle, so far as known, has not become established at points far distant from the present infested territory. Nevertheless, to insure this in the future, the most stringent regulations must continue relative to the movement of nursery stock and soil.

THE ASIATIC BEETLE

The Asiatic beetle, *Anomala orientalis*, was discovered several years ago in New Haven, Conn. Since its discovery it has increased and spread, and in the spring of 1926 it was causing severe damage to lawns in approximately 27 city blocks in Westville, a suburb of New Haven. The larvæ feed on the roots of grasses and other plants and cause the complete destruction of the sod on lawns as well as injury to perennial plants such as iris, peony, and phlox. This insect is related to the Japanese beetle and its life history is somewhat similar.

Owing to the increasing damage caused by the Asiatic beetle, an emergency appropriation of \$5,000 was made available during the year by Congress so that the problem of controlling this insect might be investigated. During the summer of 1926 scouting revealed that the insect was distributed generally in the southern

third of Long Island and in Westchester County, N. Y. Severe damage was caused to several large estates on Long Island where the insect was particularly abundant. Cooperating with the State of Connecticut, the department has carried on control measures for the purpose of reducing the infestation in New Haven. The treatment employed consisted in the application of emulsified carbon disulphide to the soil as is done for the control of the Japanese-beetle larvae in lawns. In all, 366 properties ($43\frac{1}{2}$ acres) were treated. Thirty-eight thousand pounds of concentrated carbon-disulphide emulsion and over 800,000 gallons of water were used. The soil treatment has been very effective in reducing the number of grubs throughout the New Haven area. A small laboratory was established at Westbury, Long Island, in the spring of 1927 and an investigator stationed at that point to make detailed studies of the insect and means for its control. Several parasites imported from the Orient which are effective on the Japanese beetle are also effective on the Asiatic beetle, and releasements have been made in the heavily infested areas on Long Island.

The Asiatic beetle is primarily a pest in the larval state to lawns and perennial plants. The adult beetles in the latitude of New York and Connecticut apparently feed only to a limited extent, the only damage by them that has been reported being injury to the blossoms of roses and hollyhocks.

THE JAPANESE GARDEN BEETLE

Late in July, 1926, a heavy infestation of beetles new to this country was discovered at Mount Vernon, N. Y. These were identified as *Aserica castanea*, an insect hitherto known to occur only on the islands of Japan. It belongs to a most injurious group, and further scouting revealed the fact that it had been established in northern New Jersey, eastern New York, and Long Island for several years but had been wrongly identified as a native species. This insect is commonly known as the Japanese garden beetle. The adults—small brown insects about one-half inch long—spend the greater part of the day in the soil, but emerge at night, at which time they are exceedingly active and very destructive. The adult has been observed feeding on approximately 50 different species of plants and probably feeds on many

others. These include many garden plants and fruit trees. There is evidence that its numbers have been increasing from year to year.

WORK ON THE GIPSY MOTH AND THE BROWN-TAIL MOTH

This work has continued under the direction of A. F. Burgess, and has been carried on in close cooperation with the New England States, New York, and New Jersey.

RESULTS IN NEW JERSEY

At the beginning of the year careful consideration was given to the results obtained on the gipsy-moth scouting and general clean-up work in the barrier zone and in New Jersey. On account of the progress that had been made in reducing the infested territory in New Jersey, a plan of work was adopted which provided for intensive scouting work in the towns in the central part of the area where infestation was general at the time the work began. This has to be done with great thoroughness, as it is necessary to reinspect such areas for several years after the infestations have been treated in order to be assured that they are clean. The funds applied on this project were reduced about \$30,000 from the amount spent during the previous year; therefore this central region was divided into two areas, one of which was to be given a very intensive inspection involving the examination of all trees in the area, including woodlands, while the other area, of approximately the same size, was to be given only general scouting. This arrangement contemplated that during the next year the plan would be reversed.

Owing to extremely unfavorable weather conditions in the winter of 1926 it was impossible to do any work in the town of Mendham, where a severe infestation occurred a number of years before, and this town, together with the heavily wooded areas on the Watchung Range in the northerly part of the townships of Bridgewater and Warren, and the large township of South Brunswick, were given special attention. As a result of this intensive work four gipsy-moth colonies were located in the town of Mendham, three in Bridgewater, three in Warren, and one in Bernard Township near the Bridgewater line. No infestations were found in the southern part of the territory, which includes the entire township of South

Brunswick, a portion of East Brunswick, and Montgomery. A single infestation was found in the township of Hillsboro in the area where general scouting work was done. Owing to unfavorable weather conditions small portions of North Plainfield, North Brunswick, and Montgomery, and most of Franklin Township were not examined.

No large colonies were found, and it is believed that as a result of the intensive clean-up and spraying operations conducted during the spring of 1927 the insect has been eliminated from these localities. More scouting will be required during the coming year to establish this fact.

The scouting work during the past year in New Jersey has been the most intensive and difficult that has been attempted in that region, as it has involved many large woodland areas in sections of rugged country as well as enormous swamp areas that are impassable except when frozen over. Inasmuch as all of the areas remaining to be cleaned up in New Jersey were once generally infested, it is not surprising that occasional colonies are found when very intensive work is done. The progress that has been made this year has been satisfactory, and by the close of next year, after the other half of the area has been intensively worked, it will be possible to determine how the work should be managed in order to complete the project in that State.

RESULTS IN THE BARRIER-ZONE AREA IN NEW ENGLAND AND NEW YORK

At the close of last year the plan of work in New England was revised, and it was decided to carry on intensive scouting in the towns where infestations had previously been found, and to curtail work in many of the towns that had been scouted for two consecutive years without locating the insect. A similar plan was followed in New York State in cooperation with the New York Conservation Commission. Federal work in the portion of the barrier zone lying in that State was confined to a strip of towns west of Lake Champlain extending from the Canadian border to Ticonderoga, but the entire area in Putnam was also scouted. The work was carried on very intensively in Essex, Willsboro, Chesterfield, and Moriah, as colonies of the gipsy moth had been found in the two last-mentioned towns in previous years. In the entire territory covered by the

bureau in New York State no infestations were found this year.

As a part of the plan for the work in the barrier zone in New York State, the Department of Conservation undertook the scouting of Washington County and a group of towns encircling Kingston, where an infestation was found the previous year. That office also thoroughly scouted the colonies previously found on Long Island, and began a woodland scouting campaign on the east end of the island. In addition, intensive work was done by the State in selected areas in the barrier zone in Dutchess, Columbia, and Rensselaer Counties, where colonies had previously been found. In the area surrounding Kingston two small colonies were found, one in the township of Olive and one in Rosendale. They have been carefully treated, and a belt of territory 15 miles wide has been scouted beyond these infestations. Three colonies were found on Long Island, one each at Brooklyn and Patchogue, near areas that had been previously infested, and a small colony near Montauk. These colonies have been carefully treated.

In the last annual report attention was called to the increase in the acreage of defoliation in eastern Massachusetts and New Hampshire as compared with the infestation for a few years preceding, indicating that smaller infested spots were present in widely separated areas in Massachusetts, eastern Vermont, and New Hampshire. Attention was also called to the fact that if these infestations continued to increase great difficulty would be encountered in keeping the barrier zone free from the pest.

By adopting the plan already mentioned in handling the New England portion of the zone and by taking advantage of the reduced expenditures in New Jersey, it was possible to conduct general scouting work in a number of towns east of the barrier zone in Vermont and Connecticut.

During the year 32 towns in Vermont lying directly east of the zone were examined, as well as two towns in Connecticut. Thirteen of these towns in the northern part of Vermont and the two towns mentioned in Connecticut were found not infested, and they were removed from the gipsy moth quarantined area July 1, 1927. In the remaining sector, which extends from Chittenden, Vt., southward to the Massachusetts line, three heavily infested areas were found, one each in Pittsford, Rutland, and Ira. The discovery of these colonies emphasizes

the value of this type of work, for if they had not been found during the year the infestation would have spread to some of the towns directly west that lie in the barrier zone.

In assembling available records covering conditions in towns between the Connecticut River and the barrier zone in Massachusetts it was found that the infestation, based on the number of egg clusters found, had increased 215 per cent over the year preceding and that some very large colonies had been discovered. While similar data are not available covering many of the towns east of the zone in Vermont and between the zone and the Connecticut River in Connecticut, it is known that the infestation, based on the number of egg clusters found, has materially increased.

All infestations found west of the river in Connecticut were treated by the assistants of the State entomologist, the Bureau of Entomology co-operating. Inasmuch as most of the towns west of the river in Massachusetts and Vermont had no facilities for spraying, an arrangement was made whereby two of the bureau's spraying outfits were detailed to treat the worst colonies in order to reduce the infestation and prevent spread. This work was done in 4 towns in Vermont and 13 towns in Massachusetts. All work done east of the barrier zone was made possible as a result of the savings in operation made on the New Jersey project and by the change in operating plan in the barrier zone.

At the close of the year only 1 town in the zone in Vermont was known to be infested, 8 in Massachusetts, and 7 in Connecticut. All have been thoroughly treated. A colony which was located during the year at Greenwich, Conn., which is in territory west of the zone, has been thoroughly examined, including an area for a distance of 5 miles, and no infestation has been found.

The small 1-ton truck sprayers which were perfected two years ago have been used effectively during the past season. They are particularly valuable for spraying small areas where light mobile equipment is necessary.

During the year several tests have been made for the purpose of improving and speeding up the spraying operations. Five small auxiliary pumpers were purchased which weigh about 200 pounds. By installing one of these pumpers at the water supply, which

in many cases is located so that it can not be reached by trucks for drafting water, it is possible to fill the spray tank at a distance of 700 feet if the water does not have to be raised to too high an elevation.

Another experiment has been tried by constructing a partition in the spray tank so as to divide it equally. This makes it possible to fill one side of the tank with water by using the auxiliary pumper while the solution on the other side of the partition is being sprayed. By reversing the operation continuous spraying results. The adoption of this method will increase the efficiency of the spraying outfits about 35 per cent.

QUARANTINE AND INSPECTION

The number of certificates and permits issued during the year has increased but slightly over the number issued in 1926, the total being 151,353 as contrasted with 147,694 in 1926. Practically all of this increase was in nursery-stock shipments. The number of shipments found infested was not so large as the year before, but there was about 20 per cent increase in the number of clusters found and treated. Great care has been exercised in inspecting and certifying shipments, particularly those which originate in sections known to be infested.

As in the year before, the fall and winter shipments of Christmas trees and greens were very heavy. The shipping season for these products is an extremely busy one and the volume of inspection is so great that a large number of men from the scouting force have to be detailed for this work. The total shipments were 1,011 car lots, 1,019 small lots, and 114 auto-truck shipments. There was a small decrease in the number of car-lot and auto shipments because of removal from quarantine of some of the area from which Christmas trees and greens are shipped. The trees and greens were shipped to 38 States and the District of Columbia. One small tree was consigned to Manchester, England.

FIELD AND LABORATORY RESEARCH

Foreign work has been conducted along the same lines as during the previous year, with two entomologists stationed in Budapest, where they have been studying gipsy-moth conditions in Hungary and surrounding countries, collecting parasites and shipping them to America, and making a careful

study to obtain much-needed information on the alternate hosts of some of the multibrooded gipsy-moth parasites. This information is necessary so that the different species can be intelligently handled on their arrival in this country. A third entomologist has traveled during the spring principally in Italy and the Mediterranean countries and has collected and shipped valuable material from Algeria. More than 110,000 tachinid puparia have been received from Hungary and Jugoslavia, and additional shipments have come through from Poland. Over 21,000 cocoons of a species of *Apanteles* near *vitripennis* have arrived and a limited number of another species of *Apanteles* as well as an undetermined tachinid which attacks the satin moth in Hungary.

Colonization of parasites from the Melrose Highlands laboratory totaled 7,500,000 for the year. The new species that arrived from Europe have been colonized principally in a heavily infested area in southeastern Massachusetts, while the remainder were placed in more remote infestations, principally in towns where no parasites have been colonized heretofore.

Parasitism in general has shown a slight increase over the records for the previous year, but it is far below what is necessary to check the increase of the gipsy moth. Improved methods have been devised for collecting *Calosoma* beetles in the field in order to secure information as to their abundance and to obtain specimens for colonization.

Experiments with liquid sprays and with dusts applied by airplane have resulted in the accumulation of valuable data, but further work along these lines is required. Treatment of experimental areas with lead-arsenate spray indicates that effective results can be secured if the spray is applied by the time the foliage is one-half grown. This information will serve to extend the spraying season somewhat.

A general survey of the territory indicates that the gipsy moth is more abundant and that the defoliation is more severe this year than for several years past, the defoliated acreage being approximately double what was reported last year. Large defoliated areas were not confined principally to the territory on Cape Cod this year, as thousands of acres were completely defoliated in Essex and Middlesex Counties, Mass., and large areas were in a similar condition in a number of towns near Lake Sebago, in Maine, Conway and Moultonboro, N. H., in

towns north and east of Worcester, Mass., and in the southern part of Rhode Island. The last-mentioned infestations are the most severe that have ever occurred in the southern part of that State. Present conditions indicate that more severe defoliations will result next year.

BROWN-TAIL MOTH

The brown-tail moth maintains its usual abundance in southeastern New Hampshire and southwestern Maine, but in other parts of the infested area in New England, except in a few isolated localities, it has not been seriously abundant. This species has been controlled to a very large extent during the last few years by imported parasites, which have proved more effective over a period of years than has been the case with the gipsy moth.

CEREAL AND FORAGE INSECT INVESTIGATIONS

Investigations of cereal and forage insects have been carried out under the direction of W. H. Larrimer, as formerly.

EUROPEAN CORN BORER

The severe destruction of the corn crop in southern Ontario, Canada, during 1926, as mentioned in last year's report, was viewed by hundreds of American corn growers, business men, and bankers, as well as many scientific workers, directors of experiment stations, extension workers, and others, and caused the gravest concern. The circumstances were such as to render it obvious that if some decisive steps were not taken immediately to repress the pest the heart of the Corn Belt would suffer early invasion, resulting in most serious consequences. This situation was responsible for the voluntary organization of a committee of corn growers, agriculturists, and business men, who decided that in order to cope with the existing emergency the sum of \$10,000,000 in the form of a Federal appropriation would be required. The matter was presented to the President with the indorsement of the Secretary of Agriculture and received his approval.

The plan adopted provided that the corn growers in the most heavily infested regions in New York, Pennsylvania, Ohio, Indiana, and Michigan were to be required to clean up all corn debris existing on their premises and that they were to be reimbursed to an

extent not to exceed \$2 per acre, subject to the approval of the Federal inspector, for such part of this work as was additional to that normal and usual in ordinary farm operations. Although it was conceded by all of the scientists concerned that extermination was impossible, and the entomologists of the department stated frankly that they regarded the project as a large-scale experiment in repression or control, it was felt that, in view of the obvious menace to the agriculture of the Corn Belt presented by the corn-borer problem, the project was well worth a trial; it was therefore recommended.

Ten million dollars for this project actually became available February 23, 1927, but since it was necessary to obtain State regulatory legislation to enable the project to go forward, the initiation of the work was delayed until March 14, when the first equipment was purchased and operations were begun. Under the leadership of the director of scientific work and the head of the division of cereal and forage insects all available resources of the department in Washington were coordinated and directed toward accomplishing what was undoubtedly the greatest emergency control program ever conducted under civil authority. A competent and efficient field organization was rapidly assembled by the administrative officer in charge of control, with headquarters at Toledo, Ohio. It was estimated that some 2,500,000 acres of cornland would be included in the area to be cleaned up and that the farmers could be depended upon to handle all but 500,000 acres of this, but as this area extended over a distance of some 350 linear miles from New York to Indiana, and included 64 counties, the machinery units necessarily had to be more widely scattered than otherwise would have been required.

This field clean-up campaign, conducted in cooperation with the State agricultural colleges, State departments of agriculture, and more than 300,000 farmers, came to an end on July 2 and, although weather conditions had been most unfavorable, the results attained by the farmers' own efforts were little short of marvelous. Estimates, based on actual counts, made immediately following the conclusion of the clean-up operations by men trained in this work, indicate that at least 95 per cent of the borers throughout the treated area were destroyed by this means. While the final results of this great control experi-

ment can not be ascertained until the end of the present growing season, it seems reasonable to assume that, since millions of corn borers were destroyed, the results can not fail to be of considerable benefit. During the year some 10 publications dealing with control phases of the corn-borer work have been issued, some of them in very large editions. The most essential of these were, through the cooperation of the Post Office Department, placed in the hands of each box holder on all rural routes in the clean-up area.

The corn-borer research work during the year has met with gratifying success. A general conference of State and Federal research workers was called by the director of scientific work on January 6, at which the corn-borer research program of the department was outlined in detail and the investigational phases bearing either directly or indirectly upon the problem of control were freely discussed. Although enlargement of some of the projects was arranged for, it was the general opinion of those in attendance that practically nothing had been omitted from the combined program of the department and the States. The work of introducing the parasitic enemies of the corn-borer from Europe has progressed rapidly. Nearly 500,000 of these beneficial insects had been liberated in the infested parts of Michigan, Indiana, Ohio, Pennsylvania, and New York up to June 15 of this year. Similar work in New England has resulted in placing about 1,300,000 parasites in the infested fields of that region. Six species have been recovered in the field, thus indicating their establishment in America. The publications of the year dealing with research phases of the corn-borer work have been important. They were eight in number, the most comprehensive of them being A Progress Report on the Investigations of the European Corn Borer, published as Department Bulletin 1476, consisting of 154 pages.

ALFALFA WEEVIL

The work undertaken at the alfalfa-weevil laboratory at Salt Lake City, Utah, in 1927, included field tests of airplane dusting; the study of the part played by weather conditions in determining attacks of the insect; the storage, observation, and release of imported parasites; the study of the parasites already naturalized; and the mapping of the newly infested territory. Information is being obtained which, it is hoped, will make it possi-

ble to forecast alfalfa-weevil attacks so that communities may be organized for spraying and dusting operations, using methods developed by the bureau, in ample time to reduce losses to the minimum. The importation of European parasites, chiefly the species *Anaphes pratensis*, *Anaphoidea luna*, and *Peridesmia phytonomi*, has been continued on a small scale with the cooperation of the corn-borer parasite laboratory. The spread of the alfalfa weevil has been mapped with the aid of State entomologists. No considerable extensions of the infested regions have been found except along the Wyoming-Nebraska State line. The boundary of the weevil-infested territory is now everywhere in mountainous country, where there are few fields. Recent progress in practical control methods has been embodied in Farmers' Bulletin 1528, issued during the year.

HESSIAN FLY

Very little injury by the fall generation of the Hessian fly occurred in 1926 because continuous early fall rains largely prevented early seeding of wheat. Much volunteer wheat developed, however, which in general became very heavily infested by the early fall brood and served as the main origin of a heavy spring infestation of wheat planted in 1927 in many localities throughout the main wheat belt. Spring injury was particularly severe in south-central Kansas and Oklahoma. The widespread abundance of live puparia in the 1927 stubble constitutes a distinct menace to the 1928 crop unless parasitism and weather conditions are unfavorable. A plan has been put into effect this year to coordinate the bureau's studies of this insect in order the better to systematize the work, to make it more comprehensive and efficient, and to define more clearly the objective sought.

SUGAR-CANE MOTH BORER

The work of determining an efficient and economical control of this important pest of sugar cane has been vigorously pushed during the season. The work of introducing the Cuban parasites has been resumed on a larger scale than previously. Preparations have been made to test thoroughly, during the present summer, the soaking of seed cane in cold water and the dusting of the cane with sodium fluosilicate for the destruction of the pest.

INVESTIGATIONS OF INSECTS AFFECTING STORED PRODUCTS

E. A. Back has continued in charge of investigations relating to stored-product insects.

BEAN WEEVILS

The infestation of California beans and cowpeas with bean weevils has been unexpectedly high during the year. About 70 per cent of the farmers' consignments of beans grown in San Joaquin, Stanislaus, and Merced Counties were found infested upon arrival at warehouses. The actual money lost to farmers probably exceeded \$1,000,000. The heavy infestation followed a poor market, which resulted in the holding over of many beans on the farm. These became infested in storage through lack of proper treatment, and furnished weevils for the infestation of the 1926 crop as it matured.

Since the research work of the bureau has determined the needlessness of such waste, hearty cooperation with all California agricultural agencies in the bean-growing areas has been perfected through cooperation with the California State department of agriculture. As weevil losses are registered in reductions in the amounts of cash paid farmers for the beans, it has not been difficult to conduct educational campaigns. Talks, demonstrations, and the setting aside of "bean weevil control weeks," in which business organizations have assisted, have taken place. Large numbers of samples of beans have been withdrawn from various farms and warehouses during the year for examination. These examinations have furnished data of value as a background for control. It is now recognized that community effort must supersede individual effort.

Fortunately Lima beans are seldom infested with bean weevils. At the request of the California Lima Bean Growers' Association six warehouses containing over 200,000 sacks of Lima beans grown in Ventura County, Calif., were examined for weevils late in the year, and no infestation was detected.

GRAIN INSECTS

As a result of the threatened loss to this country of the large export business in flour passing out through our southwestern ports to Europe, fol-

lowing the discovery at destination of heavy infestations by grain pests, effective cooperation has been established on the part of the Bureau of Entomology, Federal Horticultural Board, Public Health Service, Emergency Fleet Corporation, and the export millers in an attempt to suppress these pests in so far as they affect flour offered for export. It would appear that this crisis has been met successfully through control measures inaugurated in flour mills, railway stock, docks, warehouses, and ships.

The work on the Angoumois grain moth as a pest of wheat is nearing completion, the investigation having been continued along the same lines as last year. Special attention has been given to the determination of the relationship between infestation in storage and the degree of field infestation and the stage of growth that will first support the moth.

Large-scale experiments have been continued in Georgia, as during last year, for the purpose of gathering information regarding the gain to be derived from fumigation as a means of conserving stored corn from pests. The owners of one plantation in Louisiana are now effecting a saving of 3,000 bushels of corn by applying the information gained by the bureau.

DRIED-FRUIT INSECTS

The continued support by the California Dried Fruit Association of the bureau's investigation of insects destroying dried fruits and vegetables has been evidenced during the year by a contribution of \$3,000. The research work reported upon last year has been continued and a number of bulletins prepared. The lowering of insect tolerance in figs by the food, drug, and insecticide administration has forced packers to give careful consideration to the curtailment of insect infestation. The need for entomological assistance in this crisis has been met by the enlargement of the bureau's activities dealing with the control of dried-fruit pests on the farm and in the packing house. During the year a committee has been formed representative of the California Dried Fruit Association, the University of California, the California State Department of Agriculture, and the Federal Department of Agriculture, to coordinate the work on dried-fruit problems.

FUMIGANTS

Cooperative work with the Bureau of Chemistry and Soils in search of promising fumigants that do not have the fire hazard of carbon disulphide has been continued. During the year laboratory tests have been made with over 200 aliphatic compounds. As a result of these tests a considerable number of promising compounds have been discovered. Large-scale tests are now being conducted to determine the efficiency and commercial value of a number of these. Ethylene dichloride in combination with carbon tetrachloride has proved to be a comparatively cheap, efficient, nonhazardous, and non-inflammable fumigant, well adapted for use in commercial fumigating vaults. A paper has been prepared covering the experiments with this fumigant. A similar paper has been prepared covering work with a mixture of ethyl monochloroacetate and carbon tetrachloride which also shows considerable promise as a fumigant. A third paper has been prepared dealing with the alkyl formates as fumigants. Several of these show considerable value.

A number of large-scale tests with calcium cyanide and chloropicrin have been conducted in flour mills, warehouses, dwellings, and ships. Local applications of fumigants, as compared with general fumigation of the entire establishment, have been tested. The development of calcium cyanide as a fumigant for wheat in large elevator bins has been one of the big advances of the year in grain-insect control work.

FURNITURE PESTS

There has been an unusual loss during the past year because of the activity of furniture pests. Informal cooperative work has been initiated with furniture manufacturers and the producers of flax tow to determine the relative susceptibility to insect attack of various vegetable materials commonly used in upholstered furniture.

The destruction of woolen covers by insects, particularly clothes moths, has enhanced the value of the bureau's work with mothproofing solutions. Several new solutions have been developed and tested during the year. It would seem as a result of this work that certain of the better solutions have a real value when properly applied, even though they may be of no practical

value if used as they are being used by the public at large. No solution has yet been found that will permanently and absolutely protect fabrics from insect attack.

MISCELLANEOUS WORK

Incidental to other work, investigations are under way dealing with the control of stored-product insects by means of heat and of cold-storage temperatures; the relative value of cold storage and normal storage under intelligent supervision; various household pests; and the protective value against insects of odoriferous woods, such as the various species of western redwood, eucalyptus, and camphor. Investigation is also being made of the pests of candy establishments, tanneries, meat-packing plants, cereal factories, and all sorts of storage warehouses; the value of various wrappers in protecting against infestation of packaged food supplies; the value of packing under partial vacuum as a means of preventing infestation, etc. These many activities have as their object the conservation of agricultural products during storage.

TROPICAL AND SUBTROPICAL PLANT INSECT INVESTIGATIONS

Investigations of tropical and subtropical plant insects have been carried out under the direction of A. C. Baker.

CITRUS INSECTS

In connection with the project regarding oil sprays and foliage injury, sprays satisfactorily toxic to insects have been found to show varying injury to citrus foliage. The factors responsible are being isolated, and oils of known content built up. Improved formulas under test have greatly reduced injury. Studies of oil sprays in relation to fruit size indicate that the sprays do not cause a reduction in size, as supposed by some growers. Similar tests of the effect of oil sprays on fruit maturity indicate that early fruit should not be sprayed for a few weeks before marketing. With midseason and late varieties this is not a factor. The influence of arsenical sprays in advancing the date of fruit maturity has also been under investigation. Fruit maturity can be advanced by such sprays, but the quality is much altered. Studies of the citrus aphid show that the condition of "flush," or the period of new growth of citrus, and temperature are

the most important factors in outbreaks of this insect. Early and prompt treatment of local infestations has proved successful.

The occurrence of the Mexican fruit worm in the Rio Grande Valley of Texas has made necessary, in cooperation with the Federal Horticultural Board and the State of Texas, a campaign of eradication in the valley. By coordinating all agencies available a preliminary organization, largely of volunteers, made a thorough clean-up of all host fruits in the valley other than citrus. The board established a quarantine restricting the movement of the fruit permitted. A force to carry out inspection and to lead in future clean-up measures is being organized. Research plans as a basis for clean-up measures are under way. Such measures already adopted have thus far shown good results, no worms having been found in the valley since the campaign was completed.

BULB INSECTS

Because of the emergency in the bulb industry a laboratory was established in Washington State to supplement the laboratory in California. Work is being done on the biology and control of bulb-insect pests. Control experiments have involved the consideration of harvested bulbs, field plantings, and influence on forcing. In harvested bulbs the hot-water treatment is being perfected. One hundred per cent mortality of bulb-fly larvæ has been obtained at 60 minutes exposure. Results in terms of forcing show that the best time for the treatment of paper white narcissus with hot water is early in the season. They show also that these bulbs can not tolerate a temperature as high as 115° F. On the other hand, 110° F. gave satisfactory results. In connection with studies of bulb fumigation an apparatus has been perfected for the vaporization of carbon disulphide and is now being put under test in actual fumigation. A satisfactory control for the tulip aphid on iris has been found by the use of calcium cyanide, 2 ounces to 100 cubic feet.

FERN INSECTS

The leaf-hopper problem of the leather-leaf fern industry has been investigated by the laboratory in Florida, and a series of experiments were made which indicate that the insect can be controlled by the use of Derris extract.

AVOCADO INSECTS

The desire for importation of Guatemala avocados from Hawaii necessitated the study of these fruits as possible hosts of the Mediterranean fruit fly. Results indicate that under artificial conditions even those of the toughest skins may be attacked. These results will be supplemented by field studies.

CAMPBOR INSECTS

The continued injury by the camphor scale in Louisiana has resulted in a number of research problems, such as the measurement of the factors that influence the toxicity of oil sprays in the field, and the measurement of the influences that condition growth and host responses in the camphor scale. Results show that climatic factors such as air movement are important. These necessary and definite measurements, it is hoped, will permit intelligent prediction regarding the spread of the pest. A study of the biology of the Australian lady beetle has been undertaken which, it is hoped, will throw light on the whole subject of the use of parasites and predators, especially as to the failures in some work of this character.

TERMITE-PROOF BUILDINGS

In cooperation with the division of forest insects of the bureau, the Canal Zone laboratory has conducted successful termite-proofing tests. Here, where termites are very numerous, experimental buildings have remained termite free.

TRUCK-CROP INSECT INVESTIGATIONS

Investigations of vegetable and truck-crop insects have been continued under the general direction of J. E. Graf.

The latter portion of the year was notable for the unusual abundance of truck-crop pests with resulting heavy losses.

MEXICAN BEAN BEETLE

The Mexican bean beetle during the past season extended its range to a considerable extent, and infestations are now known in the North in Michigan, New York, and Canada, and in the Southeast at Norfolk, Va., and Lumberton, N. C. The intensity of infestation in the original Birmingham, Ala., area was as great in the past season as it was in 1920, the time of

its original outbreak in the eastern part of the United States, when losses to the bean crop were outstanding.

Studies on direct-control measures have been continued. Extracts of pyrethrum have shown considerable promise as a means of controlling the beetle, applicable especially to small garden areas. The cost of this material will probably, for the present at least, preclude its use on a commercial scale. Of the stomach poisons under investigation, magnesium arsenate and calcium arsenate are the most satisfactory remedies for use under average conditions. Sodium fluosilicate and other fluorides can be used to good advantage, especially against the mature beetles, but care must be taken to avoid injury to the plants.

Life-history studies have shown that while there are four generations of the insect each year in the southernmost part of the infested area, only two were produced in the more northern sections. Records on winter survival of the beetle show that there was considerable mortality in the vicinity of Columbus, Ohio, where only 1.5 per cent successfully passed the winter, whereas in Birmingham, Ala., 10 per cent of the beetles passed the winter successfully. Life-history studies of the beetle in the Southwest have confirmed earlier observations to the effect that there is only one generation annually of the insect in that region, and that it spends about 252 days of the year in hibernation. The overwintering beetles are occupied in the spring over a period of 56 days in egg laying, the eggs being in evidence from the third week in June until the middle of September. Hibernation studies in which many thousands of beetles were used show that the yellow pine-oak associations are the most favorable hibernation quarters. Beetles in hibernation cages above this zone perished. At the upper edge of the pine-oak zone the winter survival was 2.4 per cent. In the middle of the zone the survival ranged from 22 to 36 per cent. Below the zone, in the piñon or nut pine region, 2.8 per cent survived the winter, whereas in the short-grass area of the valleys all of the beetles perished.

Experiments to determine the distance of flights of the beetles resulted in recovery after 24 hours of one beetle 3 miles from the place where it was released. Another beetle after four days was found 5¼ miles from the point of liberation.

PEA APHIS

Experiments were continued on the seasonal life history and control of the pea aphid under eastern conditions. Records were obtained on the multiplication of the pest on winter hosts, dispersal, factors influencing dispersal, and seasonal abundance. The work on control measures has been confined principally to the development of a machine for collecting the pest, and the results obtained thus far have not been entirely satisfactory because of seasonal conditions and their relation to the growth of the plant. Where peas were short and hardy, the "aphidozer" could be used to good advantage, but in the case of peas which had made a very succulent growth, considerable damage accompanied the use of the machine. In California, experiments in control measures show that the pea aphid is best controlled by the use of a dust containing 3 per cent nicotine applied at the rate of 40 to 50 pounds per acre with a temperature above 70° F. Two applications are necessary before the aphids become numerous and a canvas trailer attached to the duster should be used.

SEED-CORN MAGGOT

Studies on the seed-corn maggot consisted primarily of observations on the conditions which favor the attack of the pest on newly planted potato seed pieces. It was found that maggot attack was more prevalent under conditions which were unfavorable to the rapid germination of the potatoes, and also where potatoes had been injured by applications of fertilizers directly to the rows. Organic fertilizer or decaying vegetation in the soil proved attractive to the flies for egg deposition, and in soils which contained large quantities of such materials maggot injury to potatoes was more pronounced.

The present recommendations for obviating seed-corn maggot injury to potatoes are to plant them in well-drained soil at a time which is most favorable to their rapid germination; to mix the fertilizer with the soil at least 10 days prior to the planting of the crop; and to plant potatoes at such a depth that they will not be subjected to excessive moisture or severe low temperatures.

Studies on the life history and biology of the insect show that high temperatures are a deciding factor in the activity of the fly. Although it has not been determined where or in what

stage the insect spends the summer in North Carolina, the indications are that it passes this period in the adult stage in damp and shady locations. Experiments were inaugurated to determine the relation between decay and maggot injury, and preliminary results indicate that the maggot will develop on decay-free sprouting corn and beans. Although efforts to rear the larva on bacteria-free potato seed pieces were not successful, it has not yet been definitely demonstrated that the insect will not attack sound seed potatoes. It is known, however, that conditions unfavorable to the proper corking of the cut surface of the potato furnish a favorable environment for the maggots.

STRAWBERRY ROOT LOUSE

The strawberry root louse has apparently become a most serious problem in some sections of the Chadbourn area of North Carolina. A considerable destruction of strawberry plantings during the last season was attributed to the work of this insect, although subsequent observations have shown that two other possible agencies might have been involved in the damage. The physical condition of the soil, due to the excessive use of inorganic fertilizers, followed by a dry period, or root diseases, may be responsible for a part of the injury. Further observations will be necessary to determine the exact rôle which the aphid plays in this injury. Control measures have been undertaken, but up to the present time no effective method of suppression has been developed. Studies of the biology of the strawberry root louse are under way to ascertain whether there is a vulnerable period in its life when it can be attacked by direct means.

RASPBERRY INSECTS AND MOSAICS

Studies have been continued with special reference to the insect population of raspberry plantings, with the result that three species of aphids, three of leaf hoppers, and two of plant bugs are being tested as to their connection with the transmission of virus diseases. Biological studies dealing with little-known aphids of bramble fruits are proceeding with particular reference to the possibility of their connection with these diseases. The egg, stem-mother, and sexual forms of *Aphis rubiphila*, hitherto unknown, have been discovered. Two shipments of berry plants infested with *Bembecia*

marginata and *Agrilus ruficollis* have been forwarded to New Zealand, where an effort is being made to control the berry plants, which are overrunning several important agricultural areas, by introducing their insect enemies.

SUGAR-BEET LEAF HOPPER

Quantitative studies on desert areas provided a basis for the analysis of climatic conditions for the 10 years preceding, and these were used to determine the possibility of forecasting leaf-hopper abundance. These analyses brought out a striking relationship between the character of the summer and winter preceding a crop year and the yield of beets obtained. On the basis of these data an official forecast was published through the medium of a circular letter and was made known in a series of meetings. The acreage campaign by a sugar company was based almost entirely on this information, and for the first time in the history of the industry in this territory a serious curly-top year (1926) was followed by an increased acreage, the plantings for the spring of 1927 practically doubling those of the spring of 1926. The optimism generated by the forecast was responsible for the extension of the campaign into an area generally considered submarginal as far as curly top was concerned, and that area is the only portion of the territory which is in any way affected adversely this year. Complete data on the final success of the forecast can not be made until the harvest this fall. Hibernation studies were made for use in preparing the forecast. The net effect of these studies thus far is to render very doubtful the interpretation of the relationship, previously accepted, between certain winters and the beet yields of the following year. It was previously believed that low temperatures as such were responsible for the elimination of the insect. Hibernation studies tend to show that it is not a direct relationship, since careful temperature studies of the soil surface indicate that killing temperatures were not reached.

Surveys to ascertain the distribution of the insect have been continued in collaboration with certain States and the Dominion entomological branch. The insect was discovered in Montana, and service was rendered to a sugar company prospecting the Bitterroot Valley as a potential sugar-beet area. By reason of the data accumulated by the bureau's sugar-beet laboratory in

connection with forecasting and hibernation, it was possible to make a favorable report on the project. In cooperation with the University of California an explorer was sent to the Argentine Republic in the fall of 1926, in order to obtain information on the possible occurrence of the insect there. The sugar-beet leaf hopper was not found. In cooperation with the same institution, Olive Swezy was engaged to make preliminary studies on a possible causal organism found in the leaf hopper. A substation was established at Richfield, Utah, for studying the occurrence and periods of the sugar-beet leaf hopper, both in the cultivated area and in the extensive breeding grounds in and near the Escalante Desert. A technic was devised whereby leaf hoppers could be fed on artificial culture solutions, and this has materially enlarged the scope of studies on the relationship between the insect and the disease.

TOBACCO INSECTS

TOBACCO THRIPS

Observations over several years led to the belief that Paris green was a remedy for the tobacco thrips, since these insects largely disappeared from plants on which this poison was used for flea beetles. Cage tests with thrips have now been made and show that it is unable to thrive on tobacco plants dusted regularly with Paris green.

TOBACCO WIREWORMS

Tests with poisoned bait and kainit as an insecticidal fertilizer have failed to give any conclusive results against wireworms. In the field the bran-sodium fluosilicate bait seemed to give some protection to the tobacco plants, but this was not borne out in cage experiments. The most consistently beneficial results followed the use of stocky, vigorous plants, which seemed to be able to develop in spite of wireworm attack.

TOBACCO HORNWORM

Further attempts to put the chemotropic work with the hornworm on a practical basis were made. Both amyl benzoate and amyl salicylate are excellent attractants, but the cages for trapping the moths are too bulky, and no quick-acting poison to be used in the sirup bait has been discovered, though several have been found which apparently inhibit egg laying until the death of the poisoned moth.

MISCELLANEOUS INSECTS

Further studies on the tomato fruit worm have shown that the eggs are deposited by the female moth on the fruit buds and terminal shoots of the tomato plant and that the small larvae, upon hatching, feed upon these parts for a short period and then migrate to the tomato fruit. These observations are important, since they give an indication as to when the remedy should be applied to obtain the most effective results. The destructive possibilities of this insect are indicated by egg counts made from the middle of May until the middle of July, when over this period an average of 14 eggs per plant was found.

Further experiments have been made in the use of tanglefoot screens, placed on the borders of woodlands adjacent to strawberry plantings, as an index to the emergence and movement of the strawberry weevil from hibernation into strawberry fields.

The strawberry red spider is a pest of importance in Louisiana and other sections of the South. Dusting the plants with sulphur, 3 parts, and lime, 1 part, is a most effective remedy.

The pepper weevil continues to be a serious menace to the pepper-growing areas of California. Calcium arsenate as a direct-control measure shows the most promise, but caution must be exercised in its use, since Chile peppers used for drying are likely to carry some of the arsenate to the consumer. Early applications of the poison, however, should obviate this danger. Cultural experiments indicate that the weevil may be prevented from emerging from peppers buried to a depth of 3 to 8 inches. Some measure of control results from early winter destruction of the plants by disking and plowing, and the benefits are in proportion to the care exercised in this work.

An outbreak in California of the vegetable weevil, which was discovered during the preceding season, has gained in intensity, and the insect now appears to have a firm foothold in the San Francisco Bay section. It does damage to a wide variety of crops but is especially destructive to spinach. The insect continues to be a serious pest in Mississippi, where a study of its biology and experiments in control measures are in progress. This work is being directed principally to the use of poisoned baits in order to avoid the danger of arsenical residue on food products.

In cooperation with the Florida State Plant Board studies are being continued on the celery leaf tyer. Caterpillars of this moth are apparently difficult to kill with arsenicals. Experiments have been conducted in cooperation with the Bureau of Chemistry and Soils to determine the average arsenical residue on celery resulting from the various treatments and to determine a practical method for its removal.

PHYSIOLOGICAL STUDIES

Studies of the effect of arsenicals upon the respiratory metabolism of insects have established the fact that in general arsenicals reduce the normal metabolism of insects profoundly, the extent of reduction varying with the arsenical and the concentration employed. The trivalent form of arsenic was found to be more toxic than the pentavalent form, as shown by the more intense inhibition of the respiratory metabolism of insects under experiment. An electro-Gutzeit apparatus was devised for the purpose of quantitatively determining the degree of solubility of arsenicals in the digestive system of an insect. This apparatus was found very valuable in determining accurately the quantity of arsenic necessary to kill individual insects and to determine the residual arsenic on sprayed vegetables and fruit.

COTTON-INSECT INVESTIGATIONS

Investigations of cotton insects have been carried out under the direction of B. R. Coad, as formerly.

COTTON-BOLL WEEVIL

The emergence of the cotton-boll weevil for the spring of 1927 was heavier than for any year since 1923, and weather conditions have been fairly favorable for weevil multiplication, so that damage has been fairly serious. Unfortunately, the last three years, with almost total absence of weevil damage in many districts, have given the majority of farmers a feeling of false security, and it will be necessary constantly to direct their attention to the desirability of poisoning for the insect in order to avoid serious losses due to a probable increase of the insect. The experimental areas immediately surrounding the Tallulah, La., laboratory were all overflowed by the Mississippi River about the 1st of May, and most of this land remained

under water until about July 20: there is thus but little land in cotton in the immediate section of the laboratory. Because of this shortage of cotton fields and the abnormal conditions prevailing in the neighborhood, the bureau's program of experiments for the growing season of 1927 has been materially changed and curtailed. It has, however, been possible to increase the laboratory and more technical lines of investigation to compensate for this decrease in field work. The studies of width of dust swath have been continued on a more intensive scale than before, and it is expected that another season's work will permit final conclusions which may be used as a basis for rather important modifications in the general technic of dusting. These studies have been expanded to include observations on the duration of adhesion of different types of poison under different conditions and the resultant insect control.

The work in further development of ground dusting machines is largely centered around the production of high-velocity types, utilizing either a single spreader nozzle or a single oscillating nozzle. Several such machines have been constructed and tested to determine conditions under which they can be operated and the swath widths which may be treated effectively and most efficiently under varying conditions. Commercial firms have produced tentative models of such machines in limited numbers and the experience derived from their operation is being used in checking the bureau's experimental results. After some further refinement a daylight dusting machine will be available which can be used with wind velocities of probably not over 10 miles per hour. The relation of daily weather conditions to convection or air currents is proving very important in this connection, and a series of observations on this point will be necessary before final recommendations can be made. Sufficient progress has now been made in the development of equipment for delivering dust so that this can be made to adhere to the plants when dry. A further step in this machinery development will be the perfecting of devices which can be added to various types of cultivators so that the operations of cultivation and dusting can be accomplished simultaneously.

The airplane-dusting development has continued, involving the adapta-

tion of equipment to various types of planes and the improvement of dusting technique. This has involved the development of equipment for the application of combined dusts, such as the sulphur-calcium arsenate mixture, or the calcium arsenate-nicotine mixture, with the idea of controlling a number of insect pests of the cotton plant by one and the same application.

The biological studies of the weevil at Florence, S. C., have been carried practically to completion and a manuscript is now ready for publication describing the life history and activity of the weevils under conditions existing in the Southeastern States.

COTTON FLEA HOPPER

The most striking entomological feature of the cotton-growing season of 1926 was a widespread outbreak of the cotton flea hopper. This damage appeared over the greater portion of the Cotton Belt and was very serious during the early months, consequently it was necessary to organize an extensive investigation of this comparatively new problem. The plant disorder caused by the flea hopper in many districts absolutely prevented the setting of fruit on the cotton plants until the normal period of fruiting was very nearly past. Fortunately an extremely dry summer and late fall permitted these plants to recover and make a late crop after the hoppers had left the cotton fields. Nevertheless, in many sections there was still a heavy loss of crop which can be attributed only to the hopper. Thus in Madison Parish, La., the yield of cotton for 1926 was scarcely more than one-half of that for 1925, although the acreage in cotton during these seasons was practically the same. It has been found that this plant disorder is not due to the activity of a single insect, but to a group of insects. Four different species belonging to related genera are already positively incriminated and perhaps other closely related insects will be found concerned in the same damage. A careful biological study of these insects is under way, as well as experiments in methods of control. Fairly satisfactory results have in most instances been obtained in destroying leaf hoppers through the use of dusting sulphur. There have, however, been instances of complete failure, and the best results have been obtained when dusting has been done on bright, hot, sunshiny days.

ARIZONA WEEVIL

The Arizona-weevil problem has become increasingly serious. Scouting in cultivated cotton fields in the fall of 1926 showed infestations of some years' standing throughout many new areas in southeastern Arizona where they had not been found previously. Regulatory and quarantine measures to reduce the likelihood of movement of the insect are being enforced as far as possible, and a careful check is being maintained on the old infestations which have been under observation in cultivated cotton for two or more years. A steady increase in damage by this pest in cultivated cotton has been noted. The biological investigations started some time ago have progressed to a point where weevils which have been permitted to breed on cultivated cotton for three years are under observation, and complete records are being maintained for the purpose of determining the changes in their activities which may be brought about by this change in environment. At the same time all possible information is being collected to serve as a basis for control measures. It has been found possible to obtain a fairly satisfactory degree of control of weevils hibernating in cottonseed by the use of steam sterilizers in the gins, and such a measure is now required through the entire infested area. One especially important development of the biological work has been in connection with hibernation. This weevil normally hibernates in a hard cell on the *Thurberia* plant, but with continued breeding on cultivated cotton it is noted that a fairly large percentage of the weevils leave this cell and hibernate in any available trash, in the same manner as does the ordinary boll weevil. Survival tests conducted under such conditions show that approximately 48 per cent of these weevils hibernating out of the cell survive the winter, and that about 70 per cent of those hibernating in this cell successfully pass the winter. In this connection it will be remembered that the survival of the ordinary cotton boll weevil in the Cotton Belt is only about 2.5 per cent.

COTTON APHIS

The cotton-aphis studies have been rounded out with particular reference to the interrelationship between weevil control and aphis damage. It has been found that the increase of the aphis which sometimes occurs following the

use of poison for weevil control is due partly to the destruction of parasites of the aphis and partly to the fact that the winged adult aphids seem to be strongly attracted to cotton fields which have been whitened with the dust. As a usual thing injurious infestations of aphids appear to be produced only by the application of calcium arsenate at a time not necessary for weevil control and, as far as possible, damage is being avoided by recommendations for modifying weevil applications.

PINK BOLLWORM

The pink bollworm has now become so thoroughly established along the Rio Grande in western Texas that it has reached a point in numerical abundance where biological investigations are possible. A new laboratory is being opened in western Texas for the purpose of starting an intensive study of this species in the United States. At first particular attention will be paid to those points which are of special importance in connection with regulatory, quarantine, and control measures, but at the same time a thoroughgoing fundamental study of the species is being started.

THE FLOOD IN RELATION TO INSECT DAMAGE

Following the overflows of 1927 special studies were started in Louisiana, Mississippi, and Arkansas to obtain more definite information on the relation between floods and insect damage. As is well known, certain species of insects, particularly cutworms, army worms, and grass worms, are extremely injurious following floods. It also appears that boll-weevil injury is usually severe for two or three years following an overflow. The studies organized are to determine the exact causes of these phenomena and the best methods of meeting the various insect problems created by the overflow.

INVESTIGATIONS OF INSECTS AFFECTING MAN AND DOMESTIC ANIMALS

This work has been carried on under the supervision of F. C. Bishopp, with headquarters at Dallas, Tex.

SCREW WORM

Earlier work of the bureau indicated the great protective value against screw worms of destroying the carcasses of wild and domestic animals

before the maggots have a chance to complete their growth. This practice is being rapidly adopted by ranchmen, and where carried out systematically over a considerable area has been the means of gradually reducing the screw-worm hazard. Recent severe losses from the insect have greatly stimulated interest also in the control of the screw worm by means of flytraps. The operation of these throughout considerable areas of range country has necessitated further investigations, which have been carried out in cooperation with County Agent W. R. Nisbet, of Menard County, Tex. Special effort has been made to study the many factors which influence flytrapping under range conditions. Some of these have to do with the number of traps per given area, the distribution of the traps over the ranches, the frequency of baiting and emptying traps, the kind and size of bait used, etc. As a result of last year's trapping tests in Menard County, Tex., approximately 968 gallons of flies were caught in an average of about 230 traps. Certain ranches within the trap area, upon which records were kept of the number of screw-worm cases, showed an average during the season of about 1 per cent of the stock infested, whereas on other ranches outside of the trap area, but under similar conditions, the average infestation was about 10 per cent.

CATTLE GRUBS

The control work begun last year has been continued in cooperation with the Virginia Agricultural Experiment Station. This work involved the treatment of the backs of all cattle, something over 2,300 head, in the valley known as Burkes Garden in Virginia. During the spring of 1927 the infestation of cattle which were kept in the Garden throughout the previous summer was found to be about half as heavy as that of cattle which were not grazed in the area under experimentation. This indicates that a great reduction of the grubs may be brought about by cooperative effort on the part of the stock owners, but shows the difficulty of getting complete control where the treatment is purely voluntary and not very closely supervised. Further tests have been made of powders applied to the backs of infested animals for the purpose of destroying the grubs without any preliminary treatment. These tests indicate that certain tobacco powders of high nicotine content, free nicotine dust (1 to 3

per cent nicotine), and powdered Deris root will give a high percentage of kill if applied and brushed in at intervals of about 20 days.

FLY CONTROL ABOUT DAIRIES

Extensive experiments have been carried on to determine the toxicity of various insecticides and other materials to various flies which affect cattle and contaminate dairy products. Special attention has been given to pyrethrum extracts, and comparative studies of the toxicities of extracts made from Dalmatian, Japanese, and home-grown pyrethrum flowers have been carried on. The operation of a general program for the control of flies about dairies has been continued in cooperation with the Bureau of Dairy Industry on the Beltsville farm, Md. Flies gave very little trouble on the farm during the season of 1926. Part of this immunity may have been due to climatic conditions, but undoubtedly much of it is the result of the control practices carried on.

SHEEP SCAB MITE AND GOAT LICE

The cooperative work with substation No. 14 of the Texas Agricultural Experiment Station on the sheep scab mite and goat lice was continued throughout the year. Further tests of the longevity of scab mites in pens were made, and the results further emphasize the conclusion that the reinfestation of sheep by scab mites from infested premises is not likely to take place more than a few days after the infested sheep have been removed.

POULTRY PARASITES

Further biological and control studies have been made with the fowl tick or blue bug. Tests of exposure to adverse climatic conditions, particularly cold, indicate that this pest is able to withstand very trying climatic conditions, and that it may yet greatly extend its range of destructiveness to the poultry industry.

CREeping ERUPTION OF MAN

The work on the malady known as creeping eruption has been continued in cooperation with J. L. Kirby-Smith, of Jacksonville, Fla. A very notable advance has been made in the knowledge of the causation of this troublesome malady by the demonstration that the causative organism is the larval stage of a tropical hookworm of dogs and cats, known scientifically as *Ancylostoma braziliense*.

INVESTIGATIONS OF INSECTS AFFECTING FOREST AND SHADE TREES

This work has been continued under the direction of F. C. Craighead, as in former years.

WESTERN BARK BEETLES

Although cooperation with private timberland owners and Federal officials in the technical administration of control projects has, as usual, demanded the major part of attention in the Western States, detailed biological and ecological investigations of three species of western bark beetles have been given some attention. These studies differ from those made earlier on the problem in that first consideration is being given to the environmental factors that govern the behavior of the insects themselves, the characteristics of the trees selected for attack, and the reaction of the tree itself during and after attack, in an effort to determine what influence these factors have on brood development.

Studies of the western pine beetle have brought out results that should have a wide application in matters relating to logging practice and management of forests where bark-beetle losses are a factor. By especially constructed cages it has been possible to study the reaction to beetle attack of trees of varying growth and crown characteristics. Present results indicate, other conditions being equal, that fast-growing trees offer the most resistance and slow-growing trees the least. In this respect the western pine beetle differs from the Black Hills beetle and several other important species, which are known to show little if any preference for slow-growing trees. Considerable attention was given to the predators which feed on the western pine beetle in its various stages of development. The most important of these appears to be a clerid, *Thanasimus nigriventris*. This insect is an important factor in natural control, both during the flight period, when the adults prey upon the attacking bark beetles, and during the larval stage, when the clerid larvae feed upon the bark-beetle broods. In control experiments it was found that when clerids were excluded from a section of infested tree, the emergence of the western pine beetle was as much as three times as great as when the clerids were not excluded. Life-history studies of this insect have brought out the point that in control

work it is very undesirable to treat the summer-brood trees of the western pine beetle, as these trees carry over a considerable percentage of the clerid broods until the following spring, when the adults emerge and concentrate upon the first seasonal attacks of the bark beetle.

In the Kaibab National Forest attention was given to somewhat similar investigations of the Black Hills beetle. From the results of this work it was possible to predict the phenomenal decline in the epidemic on this area, with the result that there was considerable saving in control expenditure. This decline in the epidemic appeared to be caused by the extremely dry summer, with prevailing southwest winds, which had the effect of lowering the moisture content of the trees and interfering with the developing broods of the beetle. The accumulation of predators and bark-boring larvae also played an important part in the reduction of infestation.

EFFECT OF WINDFALLS UPON BARK- BEETLE INFESTATIONS

A study of the infestations developing in and around a large windfall on the Inyo and Mono National Forests was continued during the year in cooperation with the Forest Service. The volume of timber blown down in February, 1923, was estimated at 12,500,000 feet on an area of about 32,000 acres. Nearly one-half of this loss occurred on an area of 2,640 acres where the percentage of the stand blown down ranged from 20 to more than 50. Bark beetles began breeding in this down material during the season of 1923. No damage occurred in standing trees in or around the windfalls until the fall of 1924. In August and September of that year, however, thousands of trees near the windfall areas were top-killed by *Ips oregoni*. This species promptly subsided in 1925 but during the fall of that year there was a pronounced increase in the killing of standing trees by the Jeffrey pine beetle. The 1926 infestation was found to be the heaviest in the history of the area, and there was no indication of decline from this epidemic condition. The total loss of standing timber in 1924 and 1925 was estimated at 6,000,000 board feet. About 48 per cent of this loss occurred around the areas of heaviest windfall damage. As a result of these studies it is now believed that prompt salvage of the wind-thrown trees is the only feasible meas-

ure for preventing heavy insect losses in standing timber in and around areas of heavy windfall damage.

PROBLEMS UNDER INVESTIGATION IN COOPERATION WITH FOREST EXPERIMENT STATIONS

As noted in an earlier report, a decided need has developed for assigning entomologists to the Forest Service experiment stations. Thus far, funds have been available for direct cooperation in this manner at only three of these stations, one in the New England States, one in the Lake States, and a third in the southern Appalachians.

In the New England States the investigation of the white-pine weevil, supported in part by private timberland owners, has progressed satisfactorily. Additional information on obscure points in the life history of this beetle has been obtained which will have a direct bearing on prevention of losses. These observations relate chiefly to hibernation, feeding habits, and the flight of the adults. It is now felt that direct control of the weevil under forest conditions is impractical, and reduction of the damage must be secured by proper silvicultural methods. The most advantageous and cheapest way to accomplish the desired results is to grow white pine in mixture, preferably with some species of trees which will be of value in the final crop, such as hemlocks or the better hardwoods. Indiscriminate planting of white pine without regard to suitability of the site must be discontinued.

In the southern Appalachians, investigations have been centered on a study of the southern pine beetle. Conditions were particularly favorable during the summer of 1926 and several local outbreaks on the Pisgah National Forest furnished abundant material for study. The more important developments threw further light on the causes responsible for the phenomenal rise and decline of epidemics of this beetle. It was found that there are five and sometimes six generations each season and that the ratio between progeny and parent attacking beetles indicated a possible increase of from 300 to 1,000 per cent. Experimental drought plots clearly demonstrated the susceptibility to attack of trees weakened by an insufficient supply of moisture. A sudden drop in temperature during the last winter to about

zero Fahrenheit produced a high mortality in all of the local outbreaks in the vicinity of Asheville, N. C.

In the Lake States the most important problem under study has been the tip-moth infestation on the Nebraska National Forest. The introduction of parasites was continued through large collections made on Nantucket Island, Mass., in the vicinity of Charlotte, N. C., and at Bogalusa, La. Some 8 or 10 primary parasites have been introduced, but it has not yet been determined whether any of them have become established.

COOPERATION WITH THE NATIONAL PARK SERVICE

This important work has been continued during the last year under cooperative arrangements between the National Park Service and this bureau. The entomological activities were confined to the Yellowstone, Crater, and Grand Canyon National Parks. The extensive mountain pine beetle infestation in lodgepole pine on the Crater National Park was completely cleaned up this year, and it is hoped that no further work will be necessary now that the main source of beetles (flight from the Crater National Forest to the north) has subsided. The timber along the roadways through the center of the needle-tyer infestation in the Yellowstone National Park was protected again in the last season. The green belt of timber that was sprayed stands out in striking contrast to the desolation on the more remote portions of the area. Some bark-beetle control work was done in the Yellowstone National Park and a survey of the results of bark-beetle control work in the Grand Canyon National Park demonstrated that this infestation has completely subsided.

STATUS OF THE MORE IMPORTANT BARK-BEETLE CONTROL PROJECTS

Three years of active control operations directed toward the suppression of the western pine beetle in the yellow-pine forests of southern Oregon and northern California furnished an excellent opportunity to test the efficiency of present methods of bark-beetle control and to indicate in what ways improvements might be made. During the three-year campaign, 1922-1924, nearly 400,000 acres were covered by the control operations, and 31,500 infested trees containing over 35,000,000 board feet of lumber were felled

and the bark burned, all at a total cost of approximately \$145,000. This work demonstrated the practicability of carrying on large-scale control operations through the cooperation of a number of interested owners. However, because of the shortness of the control season and the limited quantity of efficient labor in the region, there is a limit to the size of control operations in any locality during a control season, beyond which it is not practical to increase them. The most outstanding result of the work was that it proved to the timber owners that the protection of high-priced pine stock from beetle attack was a paying investment.

In Montana the Beaverhead-Bitterroot control project which was started in May, 1925, was continued during the spring of 1926, its purpose being to check the spread of a severe epidemic of the mountain pine beetle which has been sweeping south along the west side of the Continental Divide since 1910. In 1925 the front of this infestation rested upon the headwaters of the Bitterroot River, but during the past two seasons it has crossed the Continental Divide into the Beaverhead National Forest. This infestation was of such magnitude that plans for treating all of the infested trees were impossible, and a zone of defense was established across the head of the epidemic, in which some 6,500 trees were treated. Though this zone was reinfested during the past season, the work was successful in that it prevented the spread of the epidemic into areas beyond. The plan of this project contemplates treating each year the infested trees within the zone of defense until such a time as the heavy blocks of infestation to the rear, from which the reinfestation comes, have died down.

Two smaller projects in white pine were continued in cooperation with the Forest Service in 1927, one on the Pete Creek drainage of the Kootenai National Forest and another on the Independence Creek of the Coeur d'Alene National Forest. Unfortunately a severe fire swept through the latter drainage in the summer of 1926, necessitating the abandonment of further check on this project.

A severe infestation of the Black Hills beetle was reported on the Colorado National Forest. Preliminary examinations indicate 500 per cent increase of infestation over the previous year. An entomologist was stationed

there for the summer to assist in the technical features of control and to continue the general biological observations which were started on the Kaibab National Forest two years ago.

INSECTS AFFECTING FOREST PRODUCTS

Tests of wood preservatives for preventing insect attack to crude and finished forest products, as well as poisons for wood pulp and fiber products, have been continued both at Falls Church, Va., and on Barro Colorado Island, Canal Zone, Panama. Various types of mortars for brick or masonry foundation walls have been under test at Falls Church, Va., since August, 1926, to determine their relative effectiveness in preventing termites from penetrating through foundations. One type of mortar in common use failed within nine months. Increased interest has been shown by cities in several sections of the country in the adoption of suggestions for modifying city building codes to prevent damage to the woodwork of buildings. Cooperation in this work has been maintained with the National Commission of Wood Utilization, the Department of Commerce, the Forest Service, the National Lumber Manufacturers' Association, the American Wood Preservers' Association, and the Pacific Coast Building Officials' Conference.

An introduced South American termite, *Cryptotermes brevis*, already an injurious pest in southern Florida, has been discovered at New Orleans, La., and every effort has been made to stamp out this serious pest. A very destructive oriental termite, *Cryptotermes formosanus*, recently introduced into Hawaii and very injurious to the woodwork of buildings in Honolulu, has been discovered infesting the woodwork of floating docks and barges in the harbor. Since these vessels move from port to port every effort should be made to control the pest in Hawaii, and close inspections have been maintained so that this termite may be kept out of the continental United States.

INSECTS AFFECTING SHADE TREES AND HARDY SHRUBS

Excellent results have been obtained in the control of the boxwood leaf miner, conducted in cooperation with the bureau of plant industry of the Pennsylvania State Department of Agriculture. A mortality of 90 to 100

per cent has been obtained by means of hydrocyanic-acid-gas fumigation under tents, with little injury to the plants when the work is carefully done.

BEE-CULTURE INVESTIGATIONS

The work on bee culture has continued under the supervision of James I. Hambleton.

BEHAVIOR OF BEES

Work on the seasonal brood-rearing activity of colonies under normal conditions was continued and one paper was published outside of the department. The investigation of the brood-rearing activity of the leading races of honeybees was also continued, and one paper dealing with the brood-rearing activity of the Cyprian honeybee was submitted for publication by the department. A study of the brood-rearing activity of package bees during their building-up period, begun last year, was conducted on a larger scale to determine the rate of building-up of packages of various sizes and thus ascertain which size seems most economical from the building-up standpoint. A paper covering last year's work on package colonies has been submitted for publication.

Experiments dealing with the flight activities of bees have been continued, the work this year dealing particularly with methods which it is hoped will eliminate the stimulating effect upon flight brought about by the presence of nectar in the field, so that accurate information may be gained on the effects of weather factors alone.

In the experiments dealing with the reactions of bees to light the following three things have been experimentally ascertained: (1) The relative stimulating efficiency of light transmitted through certain chromatic filters has been worked out quantitatively. (2) By the use of the training method it has been found that bees can distinguish between two beams of light equal in radiant energy but diverse in wave length. (This is what would be expected from the first result mentioned, since two such beams evidently have a different stimulating effect.) (3) Conversely to (2), it has been found that bees can distinguish between two beams of light equal in wave length but diverse in radiant energy. It is hoped to ascertain whether or not bees can be trained to select light of any given wave length in the presence of light of any

other wave length, regardless of relative intensity. Several factors in the learning process are also receiving attention in these experiments; for example, how long a training period is required for bees to learn various things, how long learning is retained, and what effect the age of the bee and the season of the year have on learning.

PHYSIOLOGY OF BEES

A study of bee mortality during the winter months has been carried on. The rate of mortality is being correlated with the various weather factors and with the known condition and age of bees at the start of the winter period. By these experiments it is hoped to obtain, if possible, some accurate data on the causes of enormous losses of bees sustained annually during the winter period. It is estimated that the average winter loss throughout the United States is at least 12 per cent, and cases of losses amounting to well over 50 per cent are not uncommon. In conjunction with the study of the mortality of adult bees during the winter period, the Amoeba disease of the honeybee was discovered in two of the colonies under observation. Microscopic studies were made of the organism in order definitely to establish its identity. It turns out to be the same organism that was recently discovered in Germany. A brief description of the appearance of the parasite in the Malpighian tubules was prepared and presented for publication outside of the department. In cooperation with the Bureau of Home Economics preliminary investigations on the vitamin content of honey have been completed. Vitamins A, B, C, and D were found lacking in samples of light and dark honeys which were fed to a series of rats on diets known to be lacking in these vitamins.

DISEASES OF BEES

Eight hundred and fifteen samples of brood and adult bees have been examined for brood diseases during the year. In the United States as a whole the bee-disease situation seems to remain about the same, judging from the samples received. All importations of adult bees from foreign countries have been found to be free of *Acarapis woodi*, the mite which is causing considerable damage in Europe. The diagnostic work has brought to light a number of cases of disease the cause of which has not been ascertained.

Studies of some of these diseases are being made, and during the last year work dealing with the pathogenic relations of the fungi with the honeybee have been continued. This work has shown that the most virulent strains are of the *Aspergillus flavus-oryzae* group with the most destructive organisms existing among the strains of *A. flavus*. In addition to an earlier report describing this work, a scale dealing with all the groups of the Aspergilli and showing the relative degree of virulence among the different groups is being prepared. A study has been begun dealing with the yeasts inhabiting the honeybee. The organism *Saccharomyces apiculatus*, which has been described in France as the causative organism of the disease known as May disease, has been found to be a common inhabitant of the honeybee in America. Tests thus far here fail to show that the organism is capable of causing disease among bees, but it is actively pathogenic within the blood of bees.

BEEKEEPING REGIONS IN THE UNITED STATES

Work carried on in cooperation with the Bureau of Agricultural Economics on United States standard grades for honey has been completed and the results published in Department Circular 410. Demonstrations in grading have been given by inspectors of that bureau and a circular of instructions on grading honey has been prepared for the use of its inspection service.

INTERMOUNTAIN BEEKEEPING METHODS

A beekeeping field station was established at Laramie, Wyo., in November to carry out investigations on problems dealing with beekeeping methods peculiar to the intermountain region. The University of Wyoming has provided laboratory and office space as well as a considerable quantity of special equipment for the use of this station. A portion of the winter and spring months was utilized in becoming familiar with beekeeping practices in the intermountain States and was occupied with the many details connected with the establishment of the laboratory and experimental apiaries. The plan of work during the first year has been primarily directed along two lines, one dealing with the spread of infectious bee diseases in commercial apiaries and the other with a study of the flight activ-

ities of bees under intermountain conditions. One series of experiments dealing with the latter phase of the work has already been completed.

INSECT-PEST SURVEY

J. A. Hyslop has continued in charge of the work on the insect-pest survey.

This survey has now functioned for six years and is recognized as an integral part of the cooperative work of the bureau and the entomological agencies existing in the several States and the Dominion of Canada.

During the year the survey completed volume 6 of its monthly bulletin, comprising 10 numbers and 321 pages of text material and an index of 41 pages. A second appendix to the list of common names approved by the American Association of Economic Entomologists was also issued during the year under the supervision of the insect-pest survey.

The project to incorporate in the files of the survey the statistical data on the economic insects of North America from the literature is well advanced and a similar project to incorporate in the files of this survey such data on insects of the world has been begun. The survey files now contain references to considerably over 2,000 species of insects of economic importance in North America and about 1,500 species in foreign countries.

During the year the survey inaugurated its first field investigation, namely, that relating to methods of estimating the abundance of the black scale in the citrus groves in southern California. This project has cleared up many points and has materially advanced the action and simplified the procedure of this work. A second project—estimating the abundance of the alfalfa weevil—was started in the alfalfa fields of the Great Basin in Utah. The necessary statistical data have been accumulated and are now being studied with a view to simplifying and testing the reliability of a method now in use for this purpose.

TAXONOMIC INVESTIGATIONS

The work done on the identification and classification of insects has continued under the supervision of S. A. Rohwer. As heretofore, it has been conducted in cooperation with the National Museum, where the specialists are given desk room and where they can conduct their investigations assisted by the extensive collections of the museum.

During the year 12,243 determinations were made by the specialists assigned to this unit. Approximately 48 per cent of these identifications were for the Federal Horticultural Board, 16 per cent for other offices of the Bureau of Entomology, and the remaining 36 per cent for other institutions or for individuals. About 40 per cent of the identifications made for institutions or individuals outside the department were for specialists associated with State experiment stations, and have thus served to advance the investigations on injurious and beneficial insects carried on by the States. The identification work of this unit is of a service nature and without it the enforcement of foreign quarantines and the research conducted by other offices of the bureau and by outside agencies would be greatly hampered.

Included in the material received for identification during the year were four lots of specimens collected on cotton plants in the Southwest. The specimens are to be used as evidence in court and were received under seal. The determinations and the report thereof were prepared in the presence of witnesses, the specimens returned under seal, and the report made under oath.

Besides supplying names for specimens submitted, certain of the specialists have had time to prepare for

publication revisions of certain groups of insects. These revisions bring together the known information on the classification of the forms studied, and include descriptions of many species new to science. One of these revisions dealt with the American moths of the genus *Diatraea*, the group to which a number of injurious borers, such as the sugar-cane moth borer, belong. Another published study dealt with the larvae of weevils belonging to the genus *Bruchus*, and pointed out characters by which those species injurious to stored beans, peas, etc., can be distinguished. Still another pointed out diagnostic characters of the larvae and pupae of fruit flies occurring in this country or likely to be imported in fruits. A comprehensive study of the taxonomy of the beetles of the genus *Agrilus* has been nearly completed. This genus contains many species which feed in the larval stages in many kinds of ornamental shrubs and forest trees, and often cause considerable injury, reducing the vitality or causing the death of the plant. Besides the examples of revisionary papers cited above, many less comprehensive publications have been prepared in which many new forms have been described, and the names made available to investigators throughout the world.

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